The Medical Triage Assistant: A Diagnostic Sensor Suite for Far Forward Medical Care

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ABSTRACT

A new method for obtaining critical physiologic data in combat injured war fighters is presented. The device is called the Medical Triage Assistant (MTA). This method uses a wearable glove format that has embedded sensors for electrocardiogram (ECG), pulse oximetry and body temperature. Data is collected in real-time. Results are presented applying this device to measure physiologic changes in an anesthetized pig model subjected to hypoxia, cold induced hypothermia, and pharmacologic induced bradycardia and tachycardia. MTA data is compared to data simultaneously measured by Edwards Lifesciences Explorer, Mallinckrodt digital thermometer and Nellcor pulse oximetry. Excellent correlation was noted between data obtained by the MTA and that by traditional methods.

1.0 INTRODUCTION

In the civilian sector, clinical management of trauma has evolved into a well established approach. It begins with early intervention by well trained paramedics or emergency medical technicians (EMTs). The key element of this prehospital care is immediate stabilization and rapid evacuation to a Level 1 trauma center. At the trauma center, highly skilled medical and nursing specialists intervene to provide definitive care. Vast resources in manpower, diagnostics and therapeutics are expended on each patient. The time from injury to advanced care is expected to be less than 1 hour, the “golden hour”, an approach that has been credited with improving the clinical outcome from traumatic injury.[1]

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Although battlefield care has been traditionally based on the principals of civilian care, the application of civilian trauma to military trauma is differentiated by several key factors, and the ability to apply the principles of "golden hour" is often not possible[2]. While the military has improved forward care through the introduction of expeditionary medical units and forward surgical teams, the initial triage and management remains the responsibility of the military first provider (combat medic).

Military conditions are austere. Medical care must be administered in a resource limited, chaotic environment. Not only must the combat medic contend with multiple casualties requiring simultaneous care, care must be rendered under ground combat conditions, which can dramatically extend evacuation times. Furthermore, the combat medic generally does not have the same level of training and re-training of that of the civilian paramedic. Another confounding issue is the available resources. Highly variable evacuation time and patient load requires prudent dispensation of scare medical resources. Medical supplies are limited to what medics can carry on their back; typically this is restricted to two 1-liter I.V. fluid bags, bandages and some pharmacologic agents such as analgesics. The availability of objective physiologic data would enable the judicious management of medical resources.[3]

An important advance in trauma management has been the development of the Advanced Trauma Life Support (ATLS) [4]and Advanced Cardiac Life Support (ACLS) guidelines[5]. Physiologic data is required to properly execute these algorithms, as these treatments are clinical response driven. Civilian paramedics have portable physiologic monitors to obtain this data such as Propaks. Unfortunately, these devices are too large and heavy for practical use by combat medics. Furthermore, interpretation of this data (ECG, pulse oximetry) is not taught to the combat medic. Although the Army is in the process of implementing training to increase the combat medic skill level requirements, it is not anticipated this transition will be completed until FY 09.

In the following, we describe a new device called the Medical Triage Assistant (MTA). It measures appropriate physiologic data (i.e., ECG, pulse oximetry, body temperature) that can be applied to well-established clinical algorithms for trauma management. A potential configuration for the sensor suite is a wearable glove with processing and display capabilities on a forearm worn device. To reduce medic training requirements, automated algorithms will be used to interpret the data signals and to recommend a course of action.

The need for a portable, noninvasive inexpensive device that can provide rapid reliable physiologic data is clear. The MTA device described here is designed for use by first responders such as combat medics and civilian EMTs. The clinical utility of the MTA is expanded, as only one device is needed to care for multiple patients. Vital signs provided by the device will allow first responders to make earlier patient management decisions and initiate well established clinical guidelines, thereby optimizing the potential for positive patient outcome.

2.0 METHODS

Male adult Yorkshire pigs weighing from 30-50 kg (n=6) were used in these studies. Animals were housed and cared for under the guidelines of the NIH standards for laboratory animal care. This protocol received full approval by the USUHS Institutional Animal Care and Use Committee (IACUC).

Each pig was sedated with Ketamine (10 mg/kg, I.M.) and Xylazine (2 mg/kg, I.M.). Next, a 20g. angiocatheter was placed into an ear vein to permit administration of an intravenous anesthetic dose of pentobarbital (20mg/kg) and blood sampling. Femoral vein and artery catheters were placed. Pigs remained fully anesthetized throughout study.

For respiratory studies only, pigs were paralyzed with Pancuronium (0.1 mg/kg, I.V.) so that the rate could be varied with the ventilator setting. These pigs were intubated with an endotracheal tube and placed on mechanical ventilation. Oxygen was delivered at a FiO2 of 0.35. A Nellcor pulse oximeter was placed on the ear, a Mallinckrodt digital thermometer was placed on the pit of the left foreleg. Standard ECG surface leads were placed over the chest and connected to an Edwards Lifesciences Explorer physiologic monitor. Repeated doses of pentobarbital (5 mg/kg, I.V.) were administered every 15 minutes to maintain anesthesia. MTA sensors were placed in corresponding locations.

Bradycardia was induced with Esmolol and tachycardia induced with atropine. Hypoxia was induced by decreasing ventilator rate. Hypothermia was induced by administering cold (4^{o}C) saline, I.V.

At the conclusion of study, while still under anesthesia, pigs were euthanized with an I.V. injection of 50cc of saturated KCl solution.

Data from the traditional monitoring methods was compared to MTA data using paired t-test. ECG data was collected as discrete digital data and was also compared using the paired t-test. In addition, ANOVA was applied to data. Significant difference was predetermined to be $p<0.05$.

3.0 RESULTS

The results of this study are seen in the following figures.

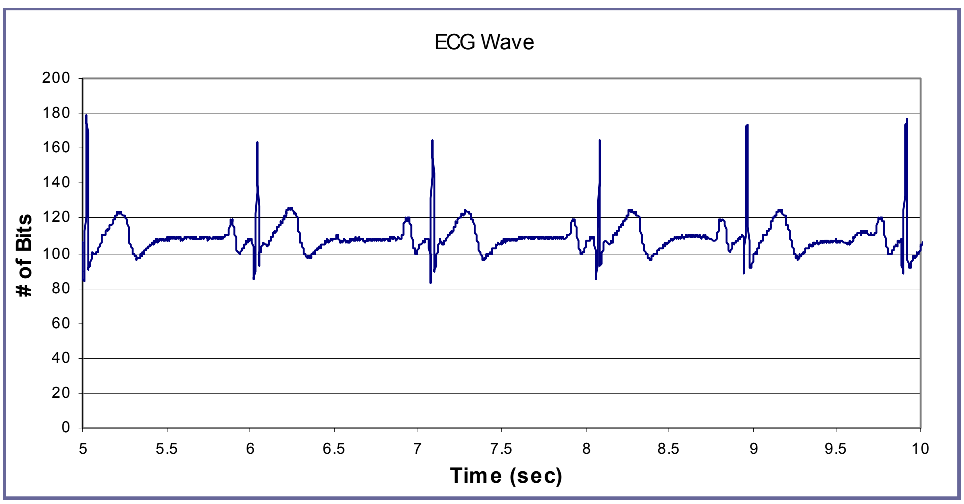
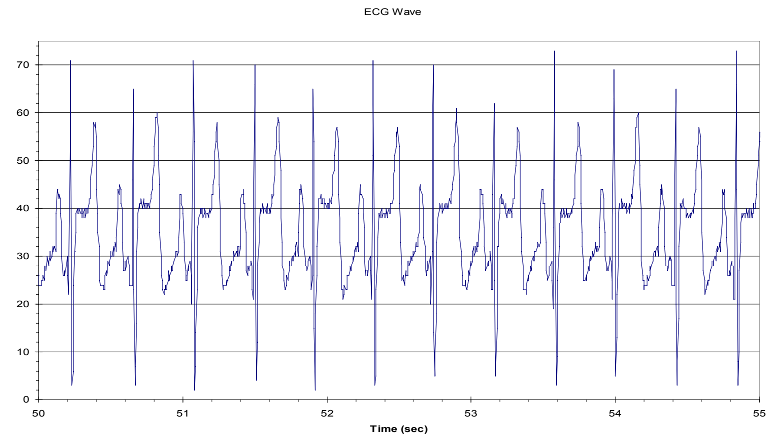


Figure 1: Bradycardia following Esmolol administration, I.V. in a representative subject.

The ECG profile obtained by the MTA during pharmacologically induced bradycardia is shown in Figure 1, and correlates with that from the Edwards Lifesciences Explorer. Analysis showed no significant difference between the 2 groups ($p>0.05$).



ECG 120-150 bpm

Figure 2: Tachycardia following Atropine administration, I.V. in a representative subject.

The ECG profile obtained by the MTA during pharmacologically induced tachycardia is shown in Figure 2, and correlates with that from the Edwards Lifesciences Explorer. Analysis showed no significant difference between the 2 groups ($p>0.05$).

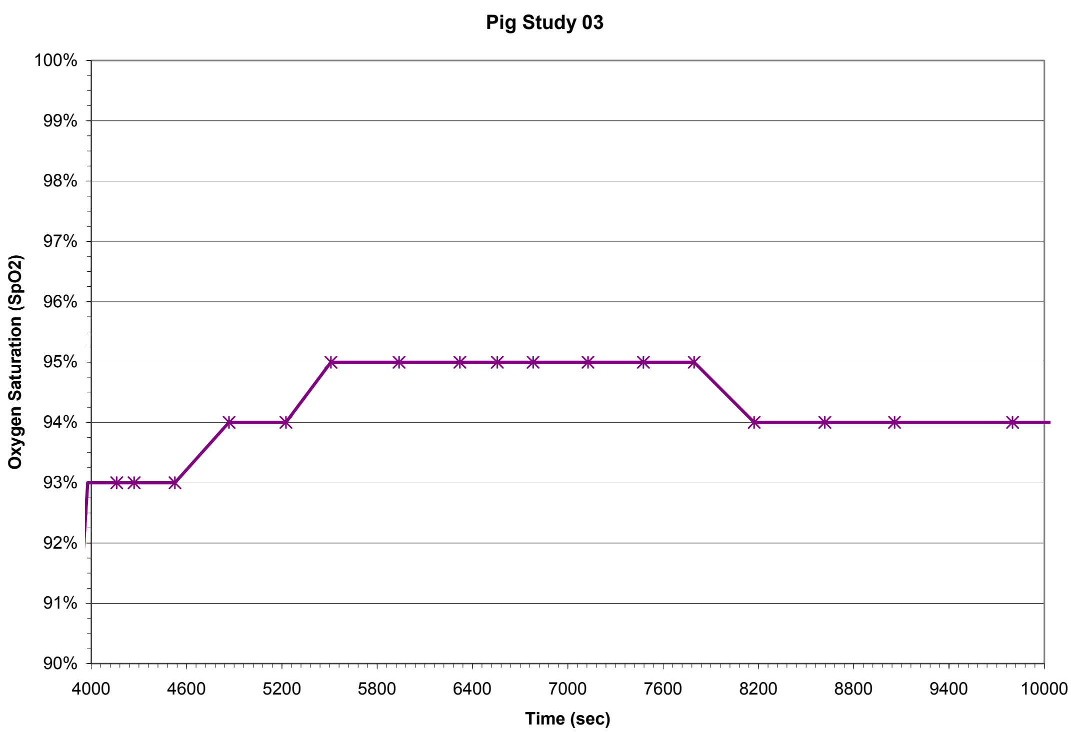


Figure 3: Pulse oximetry data in a representative subject.

The pulse oximetry data obtained by the MTA is shown in Figure 3, and closely parallels that data obtained from the Nellcor pulse oximeter. Analysis showed no significant difference between the 2 groups ($p>0.05$).

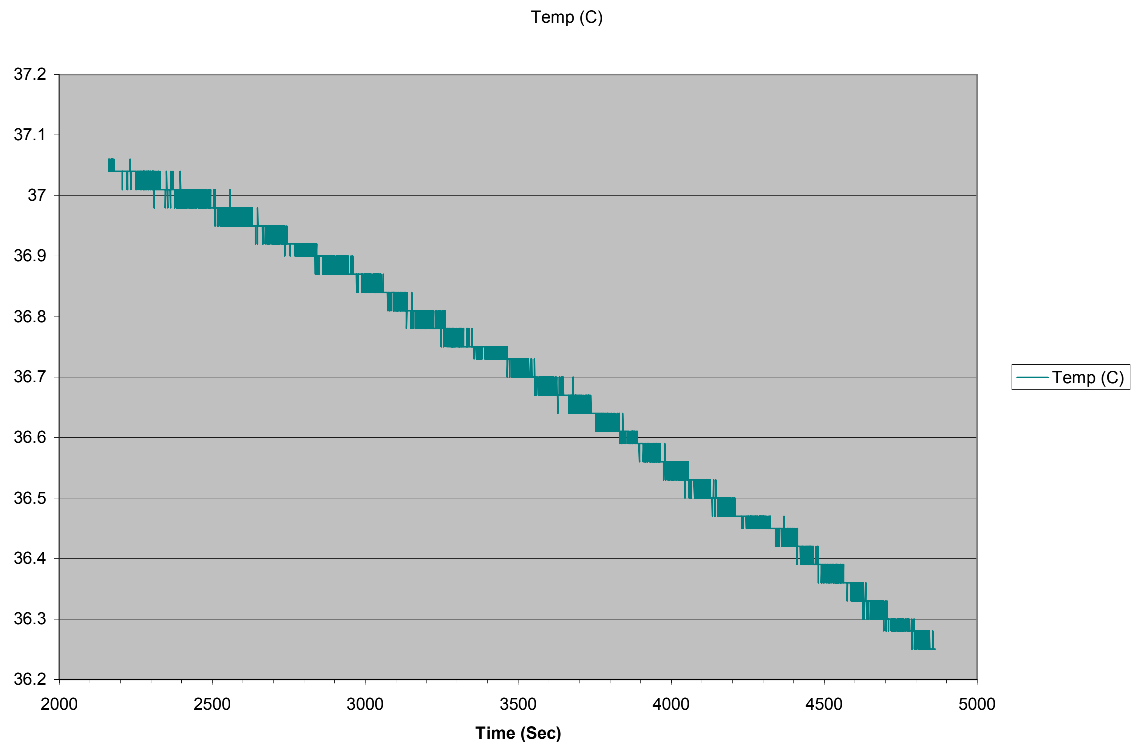


Figure 4: Body temperature following induced hypothermia in a representative subject.

Figure 4, which shows the temperature data obtained from the MTA, correlated well with that obtained from the Mallinckrodt digital thermometer. Analysis showed no significant difference between the 2 groups ($p>0.05$).

4.0 CONCLUSIONS

This study in anesthetized pigs demonstrates that the Medical Triage Assistant (MTA) is able to detect and record ECG, pulse oximetry and body temperature over physiologically relevant ranges. The data obtained by the MTA is the same as that measured by traditional methods. In addition, the data is real-time. The major difference between the MTA and currently used devices is that the MTA is much smaller and lighter.

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The opinions expressed in this work are solely those of the authors. It does not represent, express the opinion of, or imply endorsement by the U.S. Army, U.S. Navy, Uniformed Services University of the Health Sciences, Walter Reed Army Medical Center, Department of Defense or U.S. government.

6.0 REFERENCES

1. **McNicholl, B.P., *The golden hour and prehospital trauma care.* Injury, 1994. 25(4): p. 251-4.**
2. **Shoemaker, W.C., et al., *Resuscitation from severe hemorrhage.* Crit Care Med, 1996. 24(2 Suppl): p. S12-23.**
3. ***Battlefield Advanced Trauma Life Support (BATLS).* J R Army Med Corps, 2004. 150(1): p. 32-40.**
4. ***Advanced Trauma Life Support, 7th Ed.* 7 ed. 2003: American College of Surgeons.**
5. ***Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 6: advanced cardiovascular life support: section 1: Introduction to ACLS 2000: overview of recommended changes in ACLS from the guidelines 2000 conference. The American Heart Association in collaboration with the International Liaison Committee on Resuscitation.* Circulation, 2000. 102(8 Suppl): p. I86-9.**